Bank of Canada Banque du Canada

Working Paper 2001-4 / Document de travail 2001-4

On the Nature and the Stability of the Canadian Phillips Curve

by

Maral Kichian

ISSN 1192-5434

Printed in Canada on recycled paper

Bank of Canada Working Paper 2001-4

April 2001

On the Nature and the Stability of the Canadian Phillips Curve

by

Maral Kichian

Research Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
mkichian@bankofcanada.ca

The views expressed in this paper are those of the author.
No responsibility for them should be attributed to the Bank of Canada.

Contents

Acknowledgements iv
Abstract/Résumé v

1. Introduction 1
2. The Traditional Phillips Curve for Canada 3
3. A TVP Version of the Phillips Curve 8
4. Short- and Long-Run Inflation Dynamics 10
5. The Effect of Relative Price Shocks 12
6. The Coefficient on the Lagged Gap Variable 14
7. Robustness Issues 16
8. Implications for the End of the 1990s 17
9. Conclusion 18

References 20

Appendix A 21

Acknowledgements

I would like to thank Allan Crawford, Richard Dion, Pierre Duguay, Hashmat Khan, Dave Longworth, Tiff Macklem, Gabriel Srour, Gerald Stuber, and James Yetman for helpful comments and discussions. A special thanks goes to Geoff Wright and Marjorie Santos for excellent research assistance. Thanks also to Chang-Jin Kim for providing the gauss code used in the estimations.

101-04050/

Abstract

This paper empirically determines why, during the 1990s, inflation in Canada was consistently more stable than predicted by the fixed-coefficients Phillips curve. A time-varying-coefficient model, where all the parameters adjust simultaneously, shows that the behaviour of expectations was probably a major contributing factor. A decrease in the value of the coefficient on the first difference of the output gap also seems to have influenced the observed pattern of inflation. Finally, pass-through of relative price shocks into domestic prices is shown to have been low since 1983.

JEL classification: E370
Bank classification: Business fluctuations and cycles; Econometric and statistical methods; Inflation and prices

Résumé

L'auteure cherche à déterminer sur le plan empirique pourquoi l'inflation au Canada a été systématiquement plus stable, durant les années 1990, que ne le laissait prévoir la courbe de Phillips à coefficients fixes. Selon les résultats obtenus à l'aide d'un modèle à coefficients variables dont tous les paramètres s'ajustent simultanément, l'un des facteurs déterminants aurait été le comportement des attentes. Une baisse de la valeur du coefficient de la différence première de l'écart de production semble également avoir influé sur le profil d'évolution de l'inflation. L'auteure constate enfin que les chocs de prix relatifs ne se sont répercutés que faiblement sur les prix intérieurs depuis 1983.

Classification JEL : E370
Classification de la Banque : Cycles et fluctuations économiques; Méthodes économétriques et statistiques; Inflation et prix

1. Introduction

This paper empirically examines why, during the 1990s, inflation in Canada was substantially more stable than predicted by the fixed-coefficients Phillips curve. It is important to understand the reasons behind this discrepancy, because policy-makers still use the Phillips equation forecasts extensively in their policy decisions. This is not to say that these forecasts have always been highly accurate, but the systematic nature of the prediction errors over a whole decade warrants a re-examination of the nature and the stability of the curve.

Output-gap measures (Figure 1, section 2) indicate that the Canadian economy was persistently and considerably in excess supply during the first half of the decade and that the economy slowly moved into excess demand towards the end of the 1990s. According to a traditional Phillips curve, such output dynamics would *ceteris paribus* have caused inflation to initially decline, and as the gap became negative, to increase. Instead, we see that after falling sharply from 6 per cent to 2 per cent in 1991, the rate of core inflation fluctuated within a narrow band around 1.75 per cent over the next nine years. Thus, Canadian inflation was behaving rather differently than predicted by the curve, as were the inflation rates of many other developed nations over the same period. For example, in the United States, despite output levels that significantly and persistently exceeded various measures of potential GDP during the second half of the 1990s, there was no corresponding increase in inflation.[1]

Several hypotheses explain the poor forecast performance of the Phillips equation for this period: output-gap mismeasurement, anchored inflation expectations, lower pass-through of relative price shocks into domestic prices, and a decreased output-gap coefficient value. Each of these has been examined separately in the literature,[2] some within a Phillips curve context.[3] However, none of the models belonging to the latter category allow more than one postulate to affect the forecast performance of the curve. If several factors have jointly influenced this curve, the conclusions of these studies could be invalid. This paper tries to address this issue and empirically re-examines the Canadian Phillips equation taking all of the above-mentioned suggestions into account simultaneously.

---

1. Estimates of this gap were above 3 per cent at the start of 1999 according to the United States Congressional Budget Office.
2. For example, see Orphanides and van Norden (1999) for output-gap measurement concerns, Taylor (2000) for pass-through issues, and Ricketts and Rose (1995) for changing expectations owing to different Markov-switching inflation regimes.
3. An example is Dupasquier and Ricketts (1998).

A time-varying coefficient model is proposed where all the parameters of the curve follow random walks and can change every time new information becomes available.[4] This approach has a number of advantages over previous studies that used time-varying parameters in the Phillips equation.[5] First, expectations do not need to be proxied but are directly estimated. This avoids a generated regressor bias and permits a more efficient estimation of the unobserved expectations variable. Second, it is no longer necessary to restrict the number of time-varying coefficients to only a few. That is, by not making any assumptions about the causes of structural breaks, enough degrees of freedom become available to allow all the parameters of the curve to change simultaneously. Accordingly, every coefficient of the curve now adjusts optimally to new information arrivals and the different hypotheses can be examined.[6] Third, conditional confidence intervals around the estimated values can be directly obtained from the Kalman filtering procedure, providing some idea of the estimation precision.

Results show that indeed more than one factor was involved regarding the poor forecast performance of the fixed-coefficients Canadian Phillips curve during the 1990s. In particular, the behaviour of expectations and, to a lesser extent, changes in the coefficients on the gap variables seem to have played a role. In addition, pass-through of relative price shocks into domestic prices is found to have been low, not just over the 1990s but also during most of the 1980s. In contrast, the effect of exchange rates on import prices is shown to have been quite different in each of these two decades.

This paper is organized as follows. Section 2 estimates a standard augmented Phillips curve model for Canada and runs diagnostic checks. Based on the test results, section 3 proposes, estimates, and tests a time-varying-parameter (TVP) version of the model. Sections 4, 5, and 6 depict the estimated evolution of the different parameters and discuss their implications regarding the different hypotheses proposed in the literature. Section 7 conducts sensitivity analyses and reports their outcomes. Section 8 compares short-run inflation dynamics obtained from the traditional and TVP models. Section 9 concludes.

---

4. The rationale is that the curve is of a reduced form and that its parameters could be affected when underlying structural changes occur.
5. For instance, Dupasquier and Ricketts (1998) consider a proxy for inflation expectations and allow only the gap coefficient of their model to change as a function of selected variables.
6. Optimality is in a minimum root-mean-squared error sense via the application of the Kalman filter.

2. The Traditional Phillips Curve for Canada

The expectations-augmented Phillips curve expresses inflation as a function of inflation expectations, the level of current output relative to potential (i.e., the output gap), and relative aggregate price movements. Since the expectations variable is not observed, an assumption must be made about its functional form.[7] Assuming backward-looking expectations, the model can be written as:

$$\pi_t = b_0 + b_1(L)\pi_t + b_2(L)g_t + b_3(L)\Delta x_t + \varepsilon_t \qquad (1)$$

where π_t is the inflation rate, g_t is the output gap, and Δx_t captures exogenous changes in relative prices. The last term in the equation is an independently and identically distributed innovation term and $b_j(L)$ represents a lag polynomial. Finally, if the model is well-specified, the estimated expression $(\hat{b}_0 + \hat{b}_1(L)\pi_t)$ can be interpreted as being the inflation-expectations term.

To estimate equation (1) for Canada, the following variables were selected. Core inflation, defined as total inflation excluding the prices of food and energy and the effect of changes in indirect taxes, was used for the dependent variable. For the gap variable three measures were considered: 1) the extended multivariate filter (EMVF) gap, used in the Quarterly Projection Model at the Bank of Canada and obtained by applying the Hodrick-Prescott (H-P) filter to various components of output and combining them to form potential output,[8] 2) the state-space (SS) gap, obtained from an unobserved-components model, where trend output and its drift follow random walks,[9] and 3) the H-P gap, obtained by applying the H-P filter to total output. Figure 1 shows the plots of these gaps along with core inflation. Finally, the x_t variable is defined as being the inflation of imported U.S. consumption goods excluding food and energy (expressed in Canadian dollars) relative to core inflation. This variable is chosen because nearly 80 per cent of Canada's trade is with the United States and it is important to capture the effects of nominal exchange rate fluctuations on domestic prices.

---

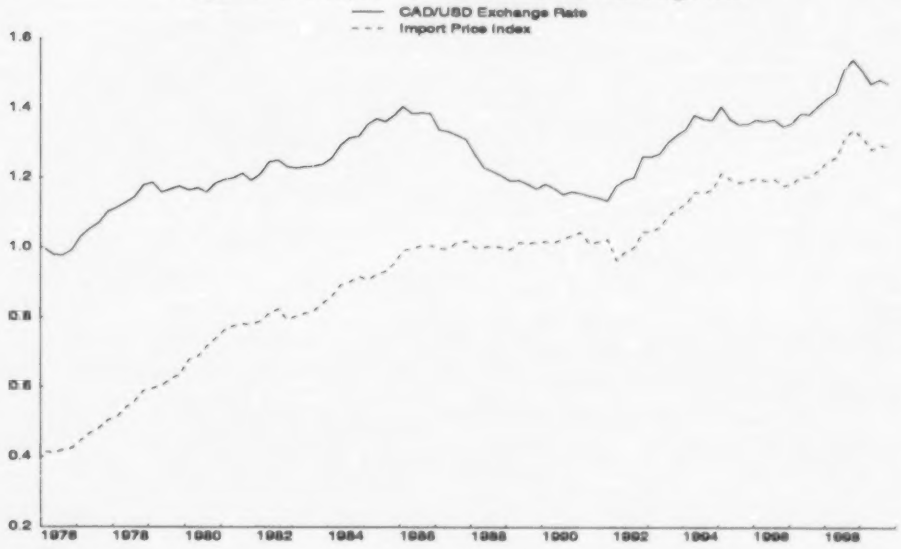
7. While some survey data try to measure expectations, usually they are not available over a sufficient duration or at the desired frequency of analysis.
8. See Butler (1996) for more details.
9. The model also incorporates a Phillips curve and is explained in Kichian (1999).

Figure 1: Gap Measures and the Inflation Rate

Figure 2 illustrates the import price level of U.S. consumption goods excluding food and energy[10] (in Canadian dollars) and the nominal Can$/US$ exchange rate. The figure shows that the dynamics of these series change over time. In particular, import prices after 1992 closely mimic the behaviour of the exchange rate, whereas, before, some important exchange rate movements were not all reflected in these prices (for instance, between 1986 and 1991). This suggests that exchange rate pass-through into import prices has increased during the 1990s[11] and that, for this same period, the coefficient on the Δx_t variable in the Phillips curve can be loosely interpreted as capturing the effect of exchange rate changes on domestic inflation.

10. See the appendix for a description of how this series was constructed.
11. Of course, part of this phenomenon could be attributed to changing import price index weights.

Figure 2: The Import Price & the CAD/USD Exchange Rate



The model was estimated with ordinary least squares on quarterly Canadian data extending from 1972Q3 to 1999Q4. Estimations were also carried out over the 1972Q3 to 1989Q4 and 1990Q1 to 1999Q4 subperiods. In each regression, the current value and first lag of the selected output gap and three lags of the Δx_t variable were used. In addition, three lags of the dependent variable were included to remove residual autocorrelation. Table 1 reports the estimation results obtained for the EMVF gap for the three samples, along with basic diagnostics.[12] The latter consist of a Ljung-Box test for no autocorrelation in the residuals over 8 or 4 lags and an LM-ARCH test for no heteroscedasticity in the residuals over 4 periods. Standard errors are calculated using heteroscedasticity and autocorrelation-consistent methods.

12. There may be some circularity in using either the EMVF or the SS gaps in the Phillips equations, because both gaps are obtained by methods that emphasize the fact that a positive gap should increase inflation. However, it is reassuring that results are qualitatively similar when a simple H-P filtered output gap is used instead.

Table 1: Estimation and test results of traditional Phillips curve with EMVF gap

Estimated coefficients (p-values)			
	1972Q3 to 1999Q4	**1972Q3 to 1989Q4**	**1990Q1 to 1999Q4**
Constant	**1.256** (0.000)	**1.270** (0.030)	**1.437** (0.001)
π_{t-1}	**0.243** (0.030)	0.225 (0.068)	0.278 (0.121)
π_{t-2}	**0.221** (0.030)	**0.259** (0.012)	-0.013 (0.914)
π_{t-3}	**0.348** (0.000)	**0.334** (0.001)	0.101 (0.412)
g_t	-0.311 (0.172)	-0.360 (0.194)	**-0.823** (0.005)
g_{t-1}	**0.719** (0.002)	**0.823** (0.002)	**0.949** (0.001)
Δx_{t-1}	**0.039** (0.023)	**0.066** (0.005)	-0.001 (0.906)
Δx_{t-2}	**0.072** (0.000	**0.109** (0.000)	0.003 (0.826)
Δx_{t-3}	**0.034** (0.058)	0.031 (0.259)	**0.025** (0.027)
Adjusted R^2	0.80	0.66	0.49
No. of obs.	107	67	40
Q-stat	8 lags; 13.1 (0.110)	4 lags; 3.4 (0.492)	4 lags; 1.1 (0.889)
ARCH(4)	4 lags; 10.4 (0.034)	4 lags; 3.7 (0.442)	4 lags; 2.1 (0.724)

Notes: Heteroscedasticity-consistent standard errors. The Q-stat is the Ljung-Box statistic, while the ARCH(4) test is an LM statistic. The highlighted values are significant at the 5 per cent level. Results for the unreported SS and H-P gap cases are qualitatively similar to those listed above.

While only the EMVF case is reported, results were qualitatively similar when either of the other two gap measures was used. These outcomes show that the coefficients of the Phillips curve have changed over time. First, the hypothesis of no heteroscedasticity is rejected at 5 per cent in the full sample but not rejected in each of the subsamples. Second, parameter values vary substantially from one sample to the other. For example, the total significant gap effect on inflation changes dramatically, from a value of 0.8 in the first subsample to about 0.1 in the second. Akerlof, Dickens, and Perry (1996) and Fortin (1996) explain that such an outcome could be the result of low-inflation targeting that leads to an increase in nominal-wage rigidity and lowers the impact of the output gap, while Beaudry and Doyle (2000) suggest that it is the improved conduct of monetary policy which leads to this outcome. Similarly, the effect of significant relative price shocks on domestic inflation drops sharply from about 0.18 to 0.03. This is especially interesting since pass-through of exchange rate movements into import prices actually increased during the

second subsample. This suggests that Canadian importers and wholesalers absorbed the pass-through into their profit margins and refrained from passing them onto Canadian consumers. Finally, the dynamics of the dependent variable are shown to have changed drastically, because the significant effect of lagged inflation on its present value drops from 0.6 in the first subsample to zero in the second. This result might indicate that expectations had become anchored during the last decade.

Taken together, the above suggest that structural changes have indeed occurred and that they have affected the Phillips relationship. In fact, it may be no coincidence that the second subsample begins with the introduction of a free-trade agreement between Canada and the United States and a policy of low inflation-targeting in Canada. To learn more about the nature of these structural changes, various Breusch-Pagan tests are applied to the regression residuals. First, the null of homoscedasticity is tested against the alternative that specific regression variables are linearly related to the variance. This determines whether inflation dynamics or changing patterns of relative price shocks are related to the parameter instability. Second, the null of no structural instability is tested against the alternative of random walk coefficients. Engle and Watson (1985) have shown that when underlying state variables change as new information becomes available, it is appropriate to model regression coefficients as random walks. Given that the Phillips curve includes an inflation-expectations term that is driven by agents' beliefs and that may be revised by new information, such a testing strategy seems relevant.

Table 2 summarizes the results from these different tests. The first three rows indicate that, regardless of the gap measure used, parameter instability is related mainly to the dynamics of inflation. Furthermore, no matter which gap is used in the estimations, the null is rejected at the 5 per cent level against the alternative that inflation coefficients follow random walk processes. The results also reveal that, with the EMVF case, the gap affects the regression variance linearly. In addition, there is some weaker evidence (i.e., at the 10 per cent significance level) that the coefficients of the EMVF gap also follow random walks. On the other hand, when the SS or H-P gaps are used, the evidence indicates that all the coefficients of the model follow such a process.

Table 2: Results of Breusch-Pagan tests against various alternatives

Alternative hypothesis	χ^2-statistic (p-value)		
	EMVF	SS	H-P
$\hat{\varepsilon}_t^2 = \alpha_0 + \alpha_1\pi_{t-1} + \alpha_2\pi_{t-1} + \alpha_3\pi_{t-3} + \nu_{1t}$	**15.0** (0.002)	**16.0** (0.030)	**13.9** (0.003)
$\hat{\varepsilon}_t^2 = \gamma_0 + \gamma_1 g_t + \gamma_1 g_{t-1} + \nu_{2t}$	**9.64** (0.008)	*4.84* (0.089)	3.20 (0.202)
$\hat{\varepsilon}_t^2 = \delta_0 + \delta_1\Delta x_{t-1} + \delta_1\Delta x_{t-2} + \delta_3\Delta x_{t-3} + \nu_{3t}$	1.60 (0.659)	0.64 (0.888)	0.57 (0.904)
All coefficients of Phillips curve are random walks	13.9 (0.125)	*16.0* (0.099)	*14.6* (0.103)
Inflation coefficients are random walks	**10.4** (0.035)	**13.1** (0.023)	**12.9** (0.012)
Gap coefficients are random walks	*5.45* (0.066)	4.32 (0.115)	2.25 (0.324)
Relative price coefficients are random walks	2.07 (0.559)	1.99 (0.575)	2.74 (0.432)

Notes: The estimated variances were obtained from regressions of equation (1). The bold values are significant at the 5 per cent level, while those in underlined italics are significant at the 10 per cent level.

The main conclusion from the Breusch-Pagan tests is that the parameter instability in the Phillips curve is strongly and significantly related to past inflation. Furthermore, the evidence supports the notion that inflation expectations change over time when appropriate information becomes available.[13] One way of integrating these findings in the Phillips equation is to put the latter in an SS framework where model parameters can be updated using the Kalman filter. Thus, agents are assumed to have a certain level of uncertainty about some of the parameters of their model (for example, the parameters of their expectations process) and they optimally update those values based on the variance of the new shocks hitting the economy relative to the prevailing uncertainty in the model. Consequently, expectations become conditionally endogenous and the model is transformed into a TVP equation. Section 3 estimates such a model.

3. A TVP Version of the Phillips Curve

In this section, a simple TVP version of the Phillips curve is estimated for Canada. The model is given by:

$$\pi_t = \beta_{0t} + \beta_{1t}\pi_{t-1} + \beta_{2t}g_{t-1} + \beta_{3t}\Delta x^a_{t-1} + \beta_{4t}\Delta g_{t-1} + \varepsilon_t \qquad (2)$$

$$\beta_{it} = \beta_{it-1} + \eta_{it} \qquad i = 0, \ldots, 4,$$

13. Most economists agree that expectations are at least partially based on past inflation behaviour.

and all errors are assumed to be uncorrelated with each other and normally distributed. To keep the system numerically tractable, one lag of each explanatory variable is included in the equation, while the relative price variable is now assumed to be the J-period average of the variable used previously.[14] Also, to better account for the effect of the position of the economy in the business cycle on inflation, the change in the output-gap variable is added to the regressors. Finally, to have maximum flexibility with fewer regressors, all the model coefficients are allowed to follow random walks.

Using maximum likelihood, the system of equations in (2) is estimated for each gap measure and Kalman filtering techniques are applied to update coefficient values.[15] For each case, twenty-six parameters are estimated: five time-varying coefficients, fifteen (distinct) elements of their conditional variance-covariance matrix, and six unconditional residual variances. Results are reported in Table 3 along with diagnostic-test outcomes.

Table 3: Estimation and test results of TVP version of Phillips curve

Unconditional variances	EMVF gap used	SS gap used	H-P gap used
	Estimate (std. error)		
σ^2_{ε}	0.098 (0.646)	0.370 (0.320)	0.302 (0.233)
$\sigma^2_{\eta 0}$	0.709 (0.183)	0.727 (0.210)	0.590 (0.183)
$\sigma^2_{\eta 1}$	0.240 (0.031)	0.210 (0.037)	0.288 (0.037)
$\sigma^2_{\eta 2}$	0.043 (0.056)	0.104 (0.111)	0.000 (0.024)
$\sigma^2_{\eta 3}$	0.007 (0.007)	0.007 (0.009)	0.000 (0.026)
$\sigma^2_{\eta 4}$	0.190 (0.110)	0.238 (0.155)	0.087 (0.050)
Q-stat(8) on errors	11.90 [0.156]	10.61 [0.225]	11.92 [0.155]
Q-stat(4) on squared errors	2.940 [0.568]	3.850 [0.427]	0.640 [0.959]

Notes: The variances are those of the error terms in equation (2). The Q-stat(8) is a Ljung-Box test on 8 lags of the heteroscedasticity-adjusted one-step-ahead forecast errors obtained from the same model, while Q-stat(4) is the same test applied to the squares of those errors, and over 4 lags. The values in square brackets represent p-values.

14. That is, $\Delta x^a_{t-1} = \frac{1}{J}\sum_{j=1} \Delta x_{t-j}$, where J equals 2, 3, or 4, depending on the gap measure used and the model fit.

15. Despite its advantages, a drawback of this modelling strategy is that it does not allow imposing positivity constraints on some of the time-varying parameters (such as the autoregressive coefficient) in a straightforward way. While Kitagawa (1987) has extended the Kalman filter theory to include general non-normality of the state-space errors, its application is numerically quite difficult and has not been attempted here. Nonetheless, it will be shown that the adopted TVP model is useful.

These show that, regardless of the gap, the estimated variances of the constant and of the lagged inflation coefficient are generally higher than those of the remaining time-varying coefficients.[16] The estimated variance of the coefficient on the first difference of the gap is also fairly high. This contrasts with the corresponding result obtained for the coefficient on the gap level. Finally, it is shown that, regardless of the gap measure used, the coefficient on relative price changes has a very small estimated variance. Therefore, the constant, the lagged inflation parameter, and the change in the output-gap coefficient were, respectively, more prone to uncertainty and they adjusted over time accordingly. In comparison, the other parameters of the model seem to have remained relatively stable over the sample period.

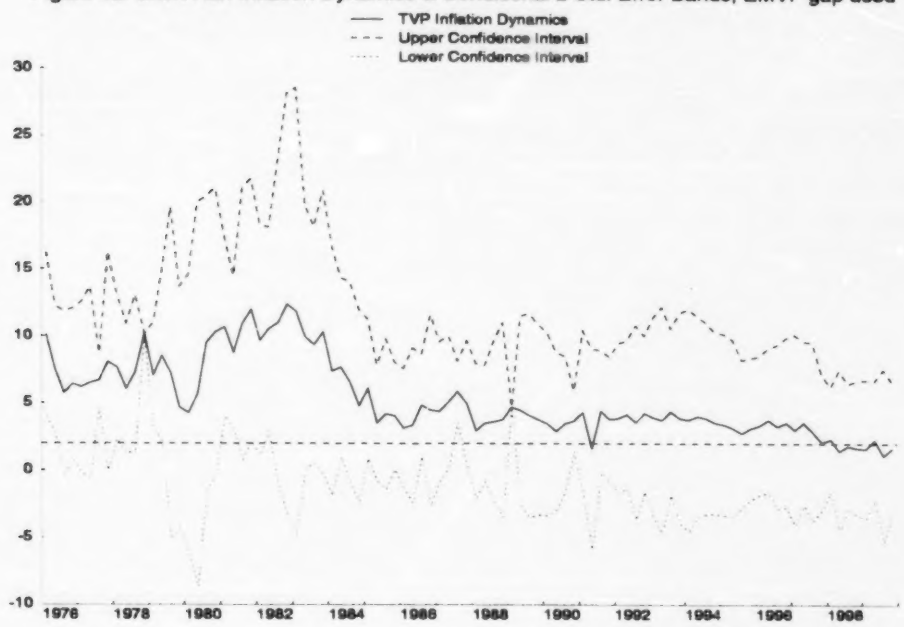
At this stage, our models are subjected to diagnostic tests. As suggested by Engle and Watson (1981), the first test checks for no serial autocorrelation in the heteroscedasticity-adjusted one-step-ahead forecast errors obtained from the model. From Table 3 note that, for all the cases, the null of no serial autocorrelation over 8 quarters is not rejected at the 5 per cent level. The second test investigates whether the heteroscedasticity that had appeared in the residuals of the traditional Phillips curve has now dissipated. That is, did the initially found ARCH effect indicate parameter instability or was some other phenomenon manifesting through heteroscedastic shocks? Again, the null of no serial correlation in the squared heteroscedasticity-adjusted one-step-ahead forecast errors is not rejected at the 5 per cent level. On the basis of these diagnostic tests, it can be concluded that the retained general TVP specification is good.

4. Short- and Long-Run Inflation Dynamics

So far it has been established that both the constant and the autoregressive coefficient of inflation exhibit a good deal of variability over time.[17] By looking at the expression $(\hat{\beta}_{0t} + \hat{\beta}_{1t}\pi_{t-1})$, it is possible to trace the estimated evolution of inflation's own dynamics. Figure 4a displays this series with estimates obtained using the EMVF gap in the model. Conditional two-standard-deviation upper and lower confidence bands are included.[18]

16. This is, of course, conditional on the validity of the standard deviation estimates associated with each of the model parameters.
17. This outcome is similar to the findings reported from regime-switching models of inflation, as in Ricketts and Rose (1995).
18. In two instances in Figure 4a the conditional confidence bands collapse to zero. This occurs when the conditional variances of the two parameters in the expression are exactly offset by their conditional covariance.

Figure 4a: Short Run Inflation Dynamics & Conditional 2 Std. Error Bands; EMVF gap used



Three main episodes distinguish the behaviour of this curve. From 1976 to about mid-1984, the series is high and quite variable. Subsequently, and until about 1992, it becomes more moderate and less variable. Finally, from 1992 until the end of the sample, it trends downwards slightly and becomes even more stable. The passage from the first to the second episode seems to coincide with the advent of the 1982 recession in Canada, whereas the last episode appears to have started around the same time as the implementation of a low-inflation targeting regime in Canada.[19]

If expectations are entirely backward-looking, then this inflation dynamics expression can be interpreted as short-run inflation expectations.[20] Assuming that this is the case, Figure 4a indicates that agents were expecting core inflation to remain stable at the 4 per cent level between 1992 and 1994. Subsequently, it seems they slowly revised their expectations downwards. Thus the series reached the 2 per cent point by 1998 and remained there until the end of the 1990s.

---

19. This policy was enacted by the Bank of Canada by establishing inflation target bands of plus and minus 1 per cent around the midpoints of a target range. The bands were implemented for total consumer price inflation and the midpoints were 3 per cent by the end of 1992 and 2 per cent by the end of 1995. The target bands have remained at the 1 to 3 per cent range since the end of 1995.

20. At the very least, if the non-controversial assumption is made that agents put some non-zero weight on past inflation, then part of this dynamics would represent inflation expectations in the short run.

To this point the discussion has centred around short-run inflation dynamics. However, the TVP model also contains information for characterizing the steady-state inflation rate. This series is given by the expression $\pi_t^{LR} = \hat{\beta}_{0t}/(1-\hat{\beta}_{1t})$ and is plotted in Figure 4b along with realized inflation.

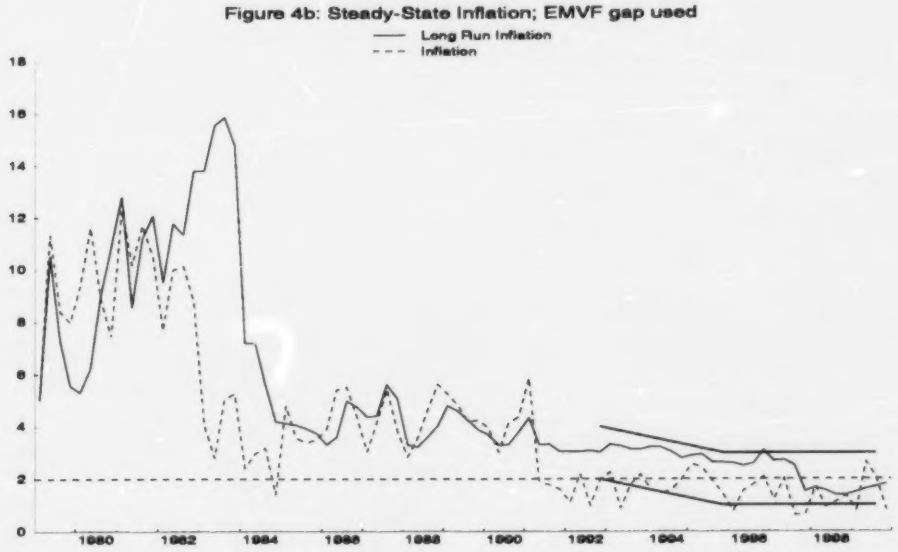


Figure 4b shows that the estimated long-run inflation rate drops from an average rate of 4 per cent during the second half of the 1980s down to about 3 per cent in 1991. Thereafter, the series appears to remain consistently within the Bank's target bands. However, while this and the realized inflation series almost coincide from 1998 onwards, during the seven years that precede, steady-state inflation is continually 1 or 2 per cent higher than actual inflation. This outcome is probably related to the fact that the output gap was quite large over this duration.

5. The Effect of Relative Price Shocks

A small open economy such as Canada's is influenced by various foreign shocks. In particular, domestic prices could be affected by factors that cause changes in import prices such as exchange rate fluctuations.[21] Nevertheless, the effect of these shocks could be subdued if firms do not

21. Studies by Dellmo (1996) and McCarthy (1999) on various industrialized countries indicate that import price changes have little effect on domestic prices. An exception is McCarthy's finding that, over the 1996–98 period (i.e., the Asian crisis), external factors did cause some disinflation in most of the countries examined.

transmit all of their cost changes into their prices. For example, there is evidence that exporting monopolistic firms in many countries adjust their destination-specific markups to remain competitive.[22] This is called pricing-to-market and it implies that import prices may not change by as much as changes in the exchange rate. Similarly, Taylor (2000) has recently argued that an environment of low inflation creates the perception that cost changes will have low persistence. As a consequence, firms might pass-through less of their cost changes into their prices, or do so more slowly.

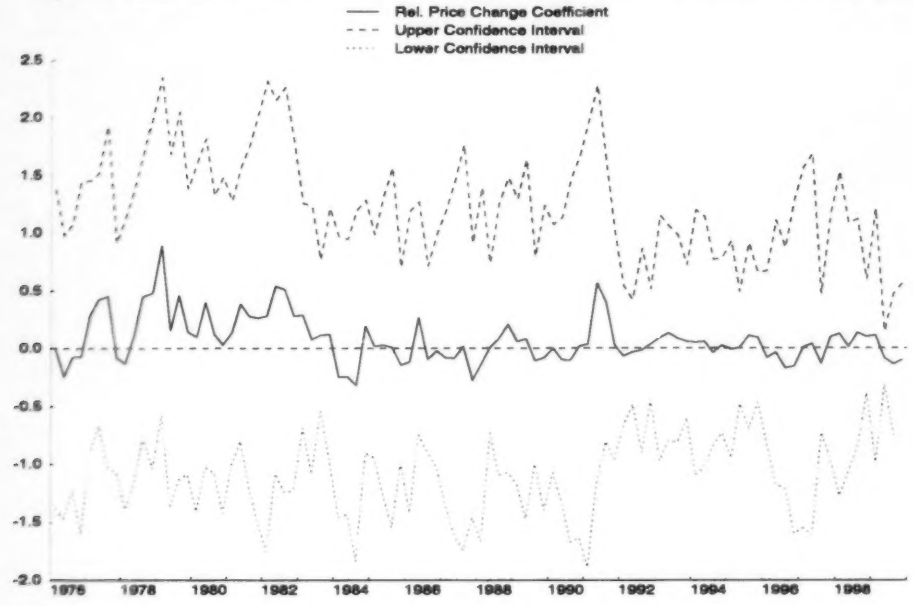
Taylor's argument implies that firms in Canada transmitted a lower portion of exogenous relative price shocks into consumer prices during the low-inflation episode of the 1990s. This outcome would be of particular interest given that Canadian import prices were more affected by exchange rate fluctuations over this period than before (see Figure 2).[23] Such a decline in pass-through could also be associated with the implementation of the North American Free Trade Agreement, which has contributed to more open and competitive trade. Thus, these two major economic changes could have jointly altered market structures and led to lower pass-through into consumer prices.

Figure 5 shows the estimated time-variation in the coefficient on changes in relative prices for the EMVF gap case. From 1976 to 1982, the average response of inflation to relative import price shocks was close to 25 per cent of the impact. However, this response decreased to practically zero and remained that way until the end of the sample. The only exception is the short-lived peak that emerges in 1991 and displays a 50 per cent response to the shock. This event could be related to one-time relative price changes that occurred after the change in Canada's tax policy was implemented (i.e., the switch from a sales tax on manufactured products to a goods and services tax).

22. See Goldberg and Knetter (1997) for an extensive survey of these studies.

23. The fact that Canadian import prices were highly subject to exchange rate fluctuations in the 1990s implies that, despite the ongoing depreciation of the Canadian dollar, U.S. exporting firms of consumer goods were not pricing-to-market. This observation is in contrast with the 1986 to 1991 appreciation of the Canadian dollar, which was accompanied by substantial pricing-to-market behaviour by U.S. exporting firms.

Figure 5: Relative Price Shock Coefficient & Conditional 2 Stdr. Error Bands; EMVF gap used



Even if they do become a little tighter over the 1990s, the conditional two-standard-deviation confidence bands are quite wide around the estimate. Nevertheless, it can cautiously be stated that Figure 5 provides some support for the Taylor hypothesis. Yet Taylor's conjecture would also have predicted a sizable difference in the effect of relative price shocks between the moderate and low inflation periods. This is not observed in Figure 5.[24] Note that results are qualitatively similar when one of the other gap measures is used.

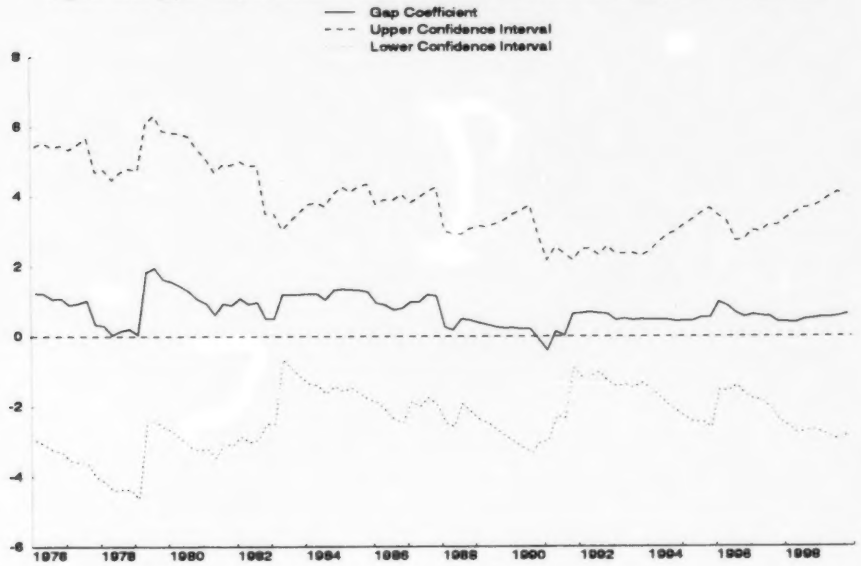
6. The Coefficient on the Lagged Gap Variable

The debate as to whether the gap coefficient in the Phillips curve recently changed has been ongoing in the literature. Some have argued that this "slope" became flatter over the 1990s. For example, Akerlof, Dickens, and Perry (1996) link this flattening to increased downward nominal-wage rigidity in the economy, engendered by the adoption of a low-inflation regime. Beaudry and Doyle (2000), on the other hand, associate the flattening with an improvement in the way monetary policy is conducted by the authorities.

24. Perhaps the precision of the estimated coefficient would have been higher, and this difference more obvious, if a positivity constraint had been imposed on this time-varying parameter.

Figure 6 shows the estimated dynamics of the lagged EMVF gap coefficient. It shows that, from 1991 to 1999, the average value of this parameter is half its 1978 to 1988 value. Moreover, the coefficient appears to have remained relatively constant during each of the two periods. On the other hand, during the transition phase in-between, the curve dips sharply to almost zero in 1988 and stays there for close to three years before recovering somewhat in mid-1991.

Figure 6: Lagged Gap Coefficient & Conditional 2 Stdr. Error Bands; EMVF gap used



Because the conditional confidence bands around the estimated coefficient are wide, it is difficult to draw firm conclusions pertaining to the Akerlof, Dickens, and Perry (1996) or the Beaudry and Doyle (2000) suggestions. Having said that, the graph seems to indicate that the link between the real side of the economy and domestic prices in the 1990s is half as strong as it used to be. In addition, it appears that this coefficient did not so much gradually flatten as undergo a one-time decrease towards the end of the previous decade.[25] However, to get a better sense of the effect of the real side of the economy on prices, it is also necessary to account for the time-varying effect of changes in the gap.

25. The results are qualitatively similar when either the SS or the H-P gap measures are used. Furthermore, outcomes are quantitatively similar when the SS gap is used.

7. Robustness Issues

According to the diagnostics that were carried out, the models listed in Table 3 seem to be specified correctly. Nonetheless, the issue of model robustness to alternative specifications is addressed. In particular, given the strong time-variation of the β_{0t} term, it is important to ascertain that this parameter does not inadvertently include some missing variable that should otherwise have been modelled explicitly. Natural choices for such absent variables are the second lags of both inflation and the gap. Also, it is necessary to make sure that results are not excessively sensitive to the time period over which the average relative import price changes are calculated.[26] Therefore, the model in equation (2) is estimated again with the following changes: 1) with a second lag of the dependent variable included, 2) with the second lag of the gap variable replacing the lagged gap difference, and 3) with an increased number of periods over which the average of the relative price shock was calculated.

As expected, adding a second autoregressive lag results in less-varying parameters and therefore smoother patterns. The only noticeable difference between the outcomes of this estimation and the previous ones is the behaviour of the estimated short-run inflation dynamics over the 1990s (especially when either the SS or the H-P gap is used in the model). Thus, the series given by the expression $(\hat{\beta_{0t}} + \hat{\beta_{1t}}\pi_{t-1} + \hat{\delta_t}\pi_{t-2})$ reaches 2 per cent inflation in 1991 and remains there until 1997 before declining somewhat.[27] If short-run inflation dynamics describes expectations, then the divergence of results has implications for the level at which expectations were anchored. As to when the lagged difference of the gap is substituted by its second lag, results indicate that, for all three gap measures, the model performance significantly deteriorates and the time-varying parameters become less-precisely estimated. Moreover, no apparent benefit could be discerned by using a longer period for the calculation of the average of the import price changes. In fact, results are either largely similar or the model simply does not converge. Finally, the estimated variance of the β_{0t} term showed no substantial difference in all the robustness experiments described.

The above outcomes thus provide some confidence that the chosen models in Table 3 are fairly robust and that their main conclusions generally hold.[28]

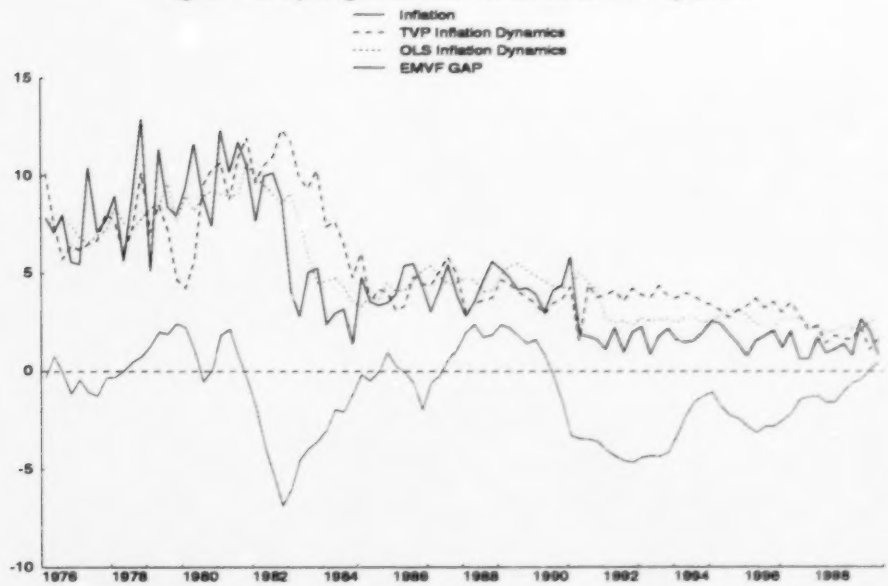
---

26. Some studies suggest that it may take up to 8 quarters before all the effects of relative price shocks are transmitted to domestic prices.
27. Note, however, that this is not very likely, since business surveys and consensus forecasts of inflation expectations indicate that this series declined to the 2 per cent mark much later than in 1991.
28. One must also admit the possibility that there is simply not enough information in the data to sufficiently distinguish these models.

8. Implications for the End of the 1990s

This section graphically compares the estimated short-run inflation dynamics of the TVP model with that of the linear Phillips curve, with particular focus on the late 1990s. That is, the series given by the two expressions $(\tilde{\beta}_0 + \tilde{\beta}_1 \pi_{t-1})$ and $(\hat{\beta}_{0t} + \hat{\beta}_{1t} \pi_{t-1})$ are contrasted, where $\tilde{\beta}_0$ and $\tilde{\beta}_1$ are obtained from an ordinary least-squares (OLS) estimation of equation (1), while $\hat{\beta}_{0t}$ and $\hat{\beta}_{1t}$ derive from the maximum-likelihood estimation of the equation (2) TVP model. Figure 7 plots these two series for the EMVF gap case, along with the graphs of core inflation and the EMVF gap.

Figure 7: Comparing OLS & TVP Short Run Inflation Dynamics



As expected, the curve obtained from the OLS version is considerably smoother than the one obtained from the conditional model. For example, unlike that of the OLS, the variance of the TVP-generated series is quite high during the highly variable inflation phase of the late 1970s and early 1980s. Also, there are long durations over which the conditional means of these series differ substantially. In particular, between 1991 to mid-1994, the TVP-produced series has a mean that is invariably higher than the OLS case. Subsequently, while the former decreases by about 1 per cent over the next three years, the latter displays no significant change in its mean. Then, the TVP-generated curve drops from close to 3 per cent inflation in 1997 to an average of about 1.5 per cent

during the last two years of the 1990s. In contrast, the mean of the OLS curve declines from a value of 2.5 per cent to slightly above 2 per cent for the same period.

To interpret these outcomes intuitively, assume that the above series of inflation dynamics represent expectations and that the TVP model generates the more realistic pattern for this variable. The poor performance of the traditional model during the 1990s can then in part be rationalized by the behaviour of short-run expectations. Thus, despite high levels of excess supply in the first half of the decade, inflation did not decline any further because short-term expectations were firmly anchored at the 4 per cent level. This can be contrasted with OLS expectations, which were lower over this period and therefore would have predicted inflation to be lower than actually observed. Next, between 1995 and mid-1997, TVP expectations came down to 3 per cent, and *ceteris paribus*, inflation should have consequently fallen. Instead, actual inflation remained at its previous average, possibly because the excess supply gap had in the meantime shrunk somewhat. Compare this to the level of OLS expectations, which were still lower and, except for 1995, would again have predicted a lower-than-realized value for the dependent variable. Finally, the narrowing and eventual closing of the gap after mid-1997 was strongly countered by the sharp decrease in TVP expectations. The latter more than offset the former and thus pushed the inflation rate to the bottom end of the target bands. In contrast, the OLS-generated expectations were a little above the 2 per cent mark during this time and, combined with a narrow gap, were calling for a higher inflation rate than realized.

9. Conclusion

Having estimated a traditional expectations-augmented Phillips curve with backward-looking dynamics for Canada, diagnostic tests conducted on the residuals suggested that the parameters of the equation may have changed over time. Indeed, it seemed that most of the structural break was linked to changing inflation dynamics and, to a lesser extent, changing gap coefficient values. Furthermore, the null of random walk behaviour could not be rejected for some of the Phillips curve regression coefficients. The model was therefore modified, and a time-varying-parameter version was estimated. This was done using maximum-likelihood methods and by applying Kalman filtering techniques to update coefficient values. Diagnostic checking and robustness estimations subsequently confirmed that the new model was well-specified according to the adopted criteria.

Plotting the evolution of the various estimated time-varying parameters of the model, it could be observed that these coefficients had indeed changed over time. However, conditional on the validity of the associated standard deviations, there was evidence that only some of these

parameters had statistically significantly evolved as random walks. These were the short-term inflation dynamics coefficients and, to a lesser extent, the coefficient on the first difference of the gap. Given the relative importance of the former, a graphical comparison was made between the evolution of the short-run dynamics series yielded by the two versions of the Phillips curve (i.e., traditional and TVP). Also, by interpreting these curves as short-run inflation expectations, some intuition was provided as to why the OLS predictions of inflation would have been higher or lower than realized.

Finally, this study shed some light on two other issues pertaining to the Canadian economy. First, given that the TVP model could provide a measure of steady-state inflation, its time evolution was estimated and discussed. Second, it was found that while pass-through of exchange rate changes into import prices had increased over the 1990s, these shocks were not transmitted to core inflation.

References

Akerlof, G., W. Dickens, and G. Perry. 1996. "The Macroeconomics of Low Inflation." *Brookings Papers on Economic Activity* 1: 1–59.

Beaudry, P. and M. Doyle. 2001. "What Happened to the Phillips Curve in the 1990s in Canada?" Proceedings of a seminar held by the Bank of Canada, June 2000. Forthcoming.

Butler, L. 1996. *A Semi-Structural Method to Estimate Potential Output: Combining Economic Theory with a Time-Series Filter.* Technical Report No. 77. Ottawa: Bank of Canada.

Dellmo, H. 1996. "Relationships Between Swedish Producer and Import Prices and the CPI." Sveriges Riksbank Working Paper No. 29.

Dupasquier, C. and N. Ricketts. 1998. "Non-Linearities in the Output-Inflation Relationship: Some Empirical Results for Canada." Bank of Canada Working Paper No. 98–14.

Engle, R.F. and M.W. Watson. 1981. "A One-Factor Multivariate Time Series Model of Metropolitan Wage Rates." *Journal of the American Statistical Association* 76: 774–81.

———. 1985. *Application of Kalman Filtering in Econometrics.* Unpublished report, World Congress of the Econometric Society, Cambridge, MA.

Fortin, P. 1996. "The Great Canadian Slump." *Canadian Journal of Economics* 29: 761–87.

Goldberg, P.K. and M. Knetter. 1997. "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature* 35: 1243–72.

Kichian, M. 1999. "Measuring Potential Output Within a State-Space Framework." Bank of Canada Working Paper No. 99–9.

Kitagawa, G. 1987. "Non-Gaussian State-Space Modeling of Nonstationary Time Series." *Journal of the American Statistical Association* 82(400): 1032–41.

McCarthy, J. 1999. "Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialised Economies." BIS Working Paper No. 79.

Orphanides, A. and S. van Norden. 1999. "The Reliability of Output Gap Estimates in Real Time." FEDS Working Paper No. 1999–38.

Ricketts, N. and D. Rose. 1995. "Inflation, Learning and Monetary Policy Regimes in the G-7 Economies." Bank of Canada Working Paper No. 95–6.

Taylor, J. 2001. "Low Inflation, Pass-Through, and the Pricing Power of Firms." Forthcoming *European Economic Review.*

Appendix A

The quarterly data used in this study are from Statistics Canada and extend from the third quarter of 1972 to the last quarter of 1999. All inflation rates are constructed by taking annualized percentage growth rates of the corresponding price levels. The categories of goods entering the construction of the Paasche import price index of consumer goods imported mainly from the United States (which exclude food and energy prices) are given by the series: d398049, d398050, d398051, d398052, d398053, d398054, d398043, and d398055. These represent the values of imported apparel and apparel accessories, footwear, printed matter, watches, sporting goods and toys, house furnishings, utensils and other household goods, photographic goods, television and radio sets, and miscellaneous inedible end products. To construct the import price index, these monthly series were transformed to quarterly frequency, their sum was divided by their volume (Bank of Canada monthly series mk92m76, converted to quarterly frequency before use), and the resulting series was annualized. The imported inflation series is thus the growth rate of this index and the x_t variable is defined as this imported inflation minus core inflation.

Bank of Canada Working Papers
Documents de travail de la Banque du Canada

Working papers are generally published in the language of the author, with an abstract in both official languages. ***Les documents de travail sont publiés généralement dans la langue utilisée par les auteurs; ils sont cependant précédés d'un résumé bilingue.***

2001

2001-3	On Commodity-Sensitive Currencies and Inflation Targeting	K. Clinton
2001-2	Exact Non-Parametric Tests for a Random Walk with Unknown Drift under Conditional Heteroscedasticity	R. Luger
2001-1	The Elements of the Global Network for Large-Value Funds Transfers	J.F. Dingle

2000

2000-23	The Application of Artificial Neural Networks to Exchange Rate Forecasting: The Role of Market Microstructure Variables	N. Gradojevic and J. Yang
2000-22	Une analyse empirique du lien entre la productivité et le taux de change réel Canada-É-U	D. Dupuis et D. Tessier
2000-21	Les effets réels du cours des actions sur la consommation	L. Pichette
2000-20	Steps in Applying Extreme Value Theory to Finance: A Review	Y. Bensalah
2000-19	Le modèle USM d'analyse et de projection de l'économie américaine	R. Lalonde
2000-18	Inflation and the Tax System in Canada: An Exploratory Partial-Equilibrium Analysis	B. O'Reilly and M. Levac
2000-17	A Practical Guide to Swap Curve Construction	U. Ron
2000-16	Volatility Transmission Between Foreign Exchange and Money Markets	S.K. Ebrahim
2000-15	Private Capital Flows, Financial Development, and Economic Growth in Developing Countries	J.N. Bailliu
2000-14	Employment Effects of Nominal-Wage Rigidity: An Examination Using Wage-Settlements Data	U.A. Faruqui
2000-13	Fractional Cointegration and the Demand for M1	G. Tkacz
2000-12	Price Stickiness, Inflation, and Output Dynamics: A Cross-Country Analysis	H. Khan
2000-11	Identifying Policy-makers' Objectives: An Application to the Bank of Canada	N. Rowe and J. Yetman

Copies and a complete list of working papers are available from:
Pour obtenir des exemplaires et une liste complète des documents de travail, prière de s'adresser à:

Publications Distribution, Bank of Canada
234 Wellington Street, Ottawa, Ontario K1A 0G9
E-mail: publications@bankofcanada.ca
Web site: http://www.bankofcanada.ca

Diffusion des publications, Banque du Canada
234, rue Wellington, Ottawa (Ontario) K1A 0G9
Adresse électronique : publications@banqueducanada.ca
Site Web : http://www.banqueducanada.ca